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Estimation of aboveground biomass of different mangrove trees based on canopy diameter and tree height

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Abstract

Determination of aboveground biomass (AGB) is an important step in planning the protection and sustainable use of mangrove resources. In the present paper, allometric relationships for estimating AGB of different morphology mangrove trees on the basis of canopy diameter (CD) and tree height (H) were studied. By comparing of correlation between AGB and CD^2*H, and of relative error rates between measurement value and simulation value within the three mangrove specie, results show that regression equation, in the form of $AGB=a(CD^2*H)^b$, is very suitable for estimation of AGB of multi-stemmed mangrove trees such as *Aegiceras corniculatum,* and is not suitable for single-stemmed mangrove trees such as *Kandelia candel*, but may be applied to those mangrove trees between multi-stemmed and single-stemmed in morphology such as *Avicennia marina*.

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Key words: aboveground biomass, canopy diameter, tree height, allometric relationship, mangrove trees

1. Introduction

Plant plays an important role in an ecosystem and biomass of plant strongly affects structure and function of ecosystem. Determination of aboveground biomass (AGB) is an important step in planning the protection and sustainable use of mangrove resources (Medeiros and Sampaio 2008). Biomass determination can be done in a direct way, by cutting and weighing all the plants in sample areas. This requires considerable effort and time, destroys the vegetation in these areas and, in some situations, is not desirable or may even be illegal. Therefore, allometric relationships for estimating AGB of mangrove trees from measurements of stem diameter at breast height (DBH) and tree height (H) have been devised and reported by a number of workers (Tam et al. 1995; Saintilan 1997; Clough *et al.* 1997; Ross et al. 2001 Liao et al. 2004; Comley and McGuinness 2005; Cue and Ninomiya 2007; Komiyama et al., 2008; Medeiros and Sampaio, 2008). It appears that most of these existing allometric relationships for

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mangroves have been based on trees with a single trunk. In some circumstances, however, a number of mangrove species produce multiple stems or main branches arising close to the ground from a single buttress or base (butt) (Clough *et al.* 1997). This type of growth pattern is characteristic of the mangroves *Aegiceras corniculatum* and *Avicennia marina* in Quanzhou Bay Estuarine Wetland of Fujian province, China. The conventional allometric relationships between biomass and stem diameter and plant height based on a single trunk may not be directly used for estimation of biomass of such type mangrove plants. To solve this problem, therefore, some studies treated each stem as a separate tree and partitioned the common biomass to each stem according to its relative diameter, and linear log–log relationships between stem diameter and the dry weights of each above-ground component were well obtained (Clough *et al.* 1997). However, this procedure was rather complex. In the present paper, we would displace DBH with canopy diameter (CD) to determine the allometric relationships for estimating total AGB of three mangrove species, *Aegiceras corniculatum*, *Avicennia marina* and *Kandelia candel* in Quanzhou Bay Estuarine Wetland, from CD and H. Thus, theprocedure of estimating total ABG would be significantly simplified.

2. Study site and Methods

2.1. Study site

Quanzhou Bay Estuarine Wetland (24°5′N and 118°46′E)) is located on the mouth of Luoyang River and is a typical semi-enclosed shallow estuarine bay. There is a total area of 876.9hm^2, of which tidal flat area of 568.5 hm^2, water area of 308.4 hm^2. The annual average temperature is 19.2℃, and annual average precipitation is 1120mm, and the average annual evaporation is about 2000mm, and the soil salinity was 3.5-28.9‰, and five species of mangrove fringe the estuary: *Aegiceras corniculatum*, *Avicennia marina, Kandelia candel, Bruguiera gymnorrioza*, and *Acanthus ilicifolius*. Three of these species, *Aegiceras corniculatum*, *Avicennia marina* and *Kandelia candel*, are native to Quanzhou Bay Estuarine Wetland and form pure stands and occur as dominants over significant area; the other two species, *Bruguiera gymnorrioza*, and *Acanthus ilicifolius*, are the newly introduced species and are found being rare in the wetland

2.2. Methods

A certain number of individuals of each of the three species were chosen to measure the indices of CD and H firstly, and then harvested all above individuals to weigh their respective fresh weight as total ABG. For these individuals, a regression equation was used to estimate AGB on the basis of CD and H, such that AGB = a $(CD^2*H)^b$, where, AGB is total aboveground biomass of mangrove individual (kg), and CD represents canopy diameter (m), and H is tree height (m). Both a and b are constants. Standard error of estimate (Se) and coefficient of determination (R^2) were synchronously obtained to evaluate the fitting .

3. Results and discussions

Measured data with respect of ABG, CD, and H for different individuals of each of three species were analyzed by using regression equation in the form of AGB = a $(CD^2*H)^{b}$, respectively. Thus the regression curves and regression equations were obtained (Table 1, Figure 1,).

. **Table 1** Regression equation for different mangrove species

Species	n	Equation	R^2	Se	Degree of correlation
Aegiceras corniculatum	16	$AGB=3.1253(CD^2*H)^{0.9063}$	0.9933	0.2785	Significant correlation
Avicennia marina	17	$AGB=1.8247(CD^2*H)^{1.0202}$	0.9762	0.3584	Significant correlation
Kandelia candel	15	$AGB=2.5904(CD^2*H)^{0.9987}$	0.8470	1.7002	Significant correlation

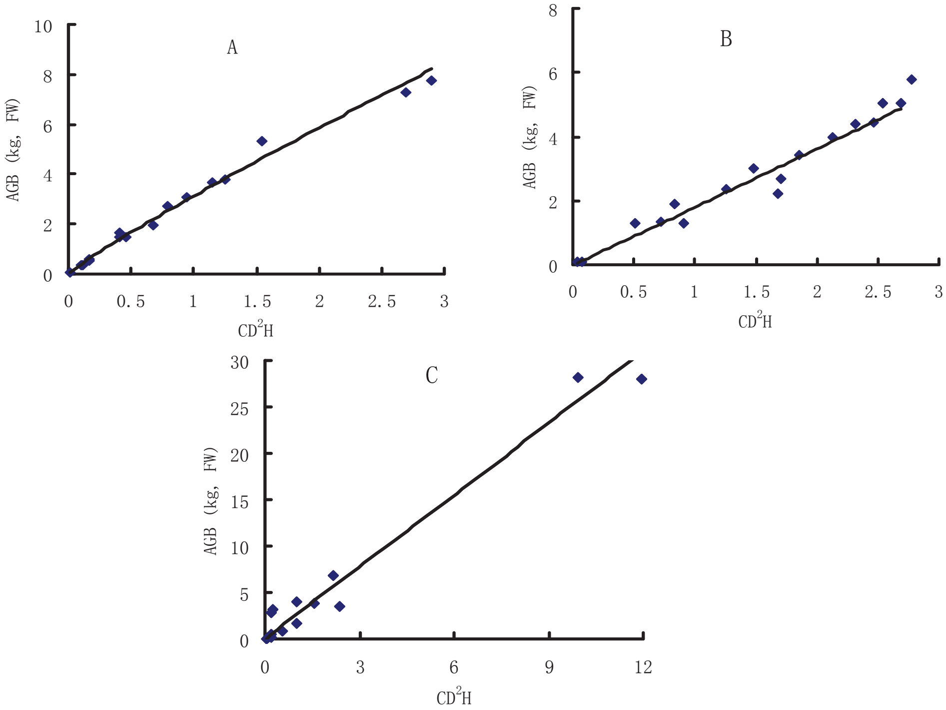

Figure 1 Curves of regression equation for different mangrove species
Note: A, B,C represents curve of regression equation of Aegiceras corniculatum, Avicennia marina, and Kandelia candel , respectively.

From Table1, it is able to be found that of three species, *Aegiceras corniculatum* demonstrated the greatest correlation between AGB and CD^2*H with an R^2 value of 0.9933 and a Se value of 0.2785, and reached the level of significant correlation. The lowest R^2, 0.8470, and the greatest Se, 1.7002, was for the relationship between AGB and CD^2*H within *Kandelia candel*, and also reached the level of significant correlation. All these results showed that, as a whole, there were strong linear relationships between AGB and CD^2*H within the three mangrove species, and as regards degree of correlation: *Aegiceras corniculatum*＞*Avicennia marina*＞*Kandelia candel*. Figure 1 also shows a better fitting result within the three mangrove species.

Although above regression analysis showed strong linear relationships between AGB and CD^2*H within the three mangrove species, it can not quantitatively express the fitting results of regression equations. In the present paper, the relative error rates between measurement value and simulation value within the three mangrove species were calculated to and to test fitting results of regression equation (Table 2). The information from Table 2 shows that: (1) Of 16 relative error rates between measurement value and simulation value for *Aegiceras corniculatum*, ten ones were lower than 10%, accounting for 62.5% of total sampling number; and other six ones were lower than 15.5%, which indicated that the regression equation of AGB=3.1253 $(CD^2*H)^{0.9063}$ can well estimate AGB of *Aegiceras corniculatum* based on the two indices of CD and H. (2) Of 17 relative error rates between measurement value and simulation value for *Avicennia marina*, nine ones were lower than 10%, accounting for 52.9% total sampling number; and however, five ones were greater than 20%, accounting for 29.4% total sampling number. Therefore, the regression equation of AGB=1.8247 $(CD^2*H)^{1.0202}$ still can better estimate AGB of *Avicennia marina* based on the two indices of CD and H. (3) Of 15 relative error rates between measurement value and simulation value for *Kandelia candel*, only three ones were lower than 10%, and other eight ones were greater than 50%, accounting for 52.9% total sampling number, and even two ones were higher than 100%. Despite a significant correlation between AGB and CD^2*H within *Kandelia candel,* the above results with respect of relative error rate indicated that the regression equation of AGB=2.5904 $(CD^2*H)^{0.9987}$can not well estimate AGB of *Kandelia candel* based on the two indices of CD and H.

Table 2 The comparison of actual and theoretical values for different mangrove species

	Aegiceras corniculatum			*Avicennia marina*			*Kandelia candel*		
No.	Measurement value	Simulation value	Relative error rate (%)	Measurement value	Simulation value	Relative error rate (%)	Measurement value	Simulation value	Relative Error rate (%)
1	7.77	8.20	5.53	3.42	3.44	0.58	2.91	0.58	80.07
2	7.28	7.69	5.63	1.35	1.31	2.60	3.1	0.63	79.68
3	5.34	4.63	13.30	1.31	1.65	25.95	0.52	0.57	9.62
4	3.65	3.54	3.01	5.02	4.72	5.98	0.13	0.3	130.77
5	1.48	1.38	6.76	3.00	2.72	9.34	0.14	0.23	64.29
6	2.75	2.51	8.73	2.23	3.09	38.57	0.06	0.07	16.67
7	0.33	0.38	15.15	5.06	5.00	1.19	0.22	0.46	109.09
8	0.08	0.07	7.75	2.69	3.15	17.10	3.52	6.15	74.72
9	0.62	0.62	0	1.88	1.51	19.68	1.63	2.64	61.96
10	1.94	2.18	12.37	1.30	0.91	30.00	0.87	1.38	58.62
11	0.53	0.60	13.21	0.07	0.05	28.57	6.83	5.64	17.42
12	0.38	0.43	13.16	0.08	0.12	50.00	3.77	4.04	7.16
13	1.47	1.54	4.76	3.98	3.93	1.27	28	30.82	10.07
14	3.05	2.97	2.62	2.34	2.30	1.71	28.19	25.67	8.94
15	3.81	3.84	0.79	4.41	4.29	2.72	4.03	2.63	34.74
16	1.63	1.38	15.34	4.43	4.57	3.16			
17				5.78	5.18	10.38			

4. Conclusion

This study is one of the few to report allometric relationships for estimating AGB of mangrove trees from measurements of CD and H. Through regression analysis, it was found that there was a strong linear relationships between AGB and CD^2*H within each of the three mangrove species, with a level of significant correlation. Of three mangrove trees, the highest correlation was within *Aegiceras corniculatum,* and lowest one was within *Kandelia candel*. Further analysis of the relative error rates between measurement value and simulation value within the three mangrove species showed that the regression equation of AGB = a $(CD^2*H)^b$ can well estimate AGB for *Aegiceras corniculatum*, better for *Avicennia marina,* and poorer for *Kandelia candel*.

Substantial studies with respect of allometric relationships for estimating biomass of mangrove trees were reported. Of all these studies, most researchers often used some indices of stem diameter at breast height and/or basal diameter, and/or tree height to estimate biomass of mangrove trees and gained a good estimating result. However, due to difference in morphology of different mangrove trees, no one equation is suitable for biomass estimation of all mangrove trees. Therefore, to reach the more accurate estimation result, different indices of growth should be chosen to estimate biomass for these mangrove trees with different morphology. In the Quanzhou Bay Estuarine Wetland, *Aegiceras corniculatum* produces multiple stems or main branches arising close to the ground from a single buttress or base with a shape of sphere or hemisphere, while *Kandelia candel* is single-stemmed tree specie with a shape of umbrella, and *Avicennia marina* is between multi-stemmed and single-stemmed in morphology. By comparing the results of estimation of AGB for different morphology mangrove trees, it is obtained that allometric relationships for estimating AGB on the basis of CD and H is very suitable for multi-stemmed mangrove trees such as *Aegiceras corniculatum,* and is not suitable for single-stemmed mangrove trees such as *Kandelia candel*, but may be applied to those mangrove trees between multi-stemmed and single-stemmed in morphology such as *Avicennia marina*

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